A Review of Current Knowledge

CLIMATE CHANGE

THE FUNDAMENTALS

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This review is one of a series of Reviews of Current Knowledge (ROCKs) produced by FWR. They focus on topics related to water supply, wastewater disposal and water environments, which may be the subject of debate and inquiry. The objective of each review is to produce concise, independent scientific and technical information on the subject to facilitate a wider understanding of the issues involved and to promote informed opinion about them.

Review of Current Knowledge

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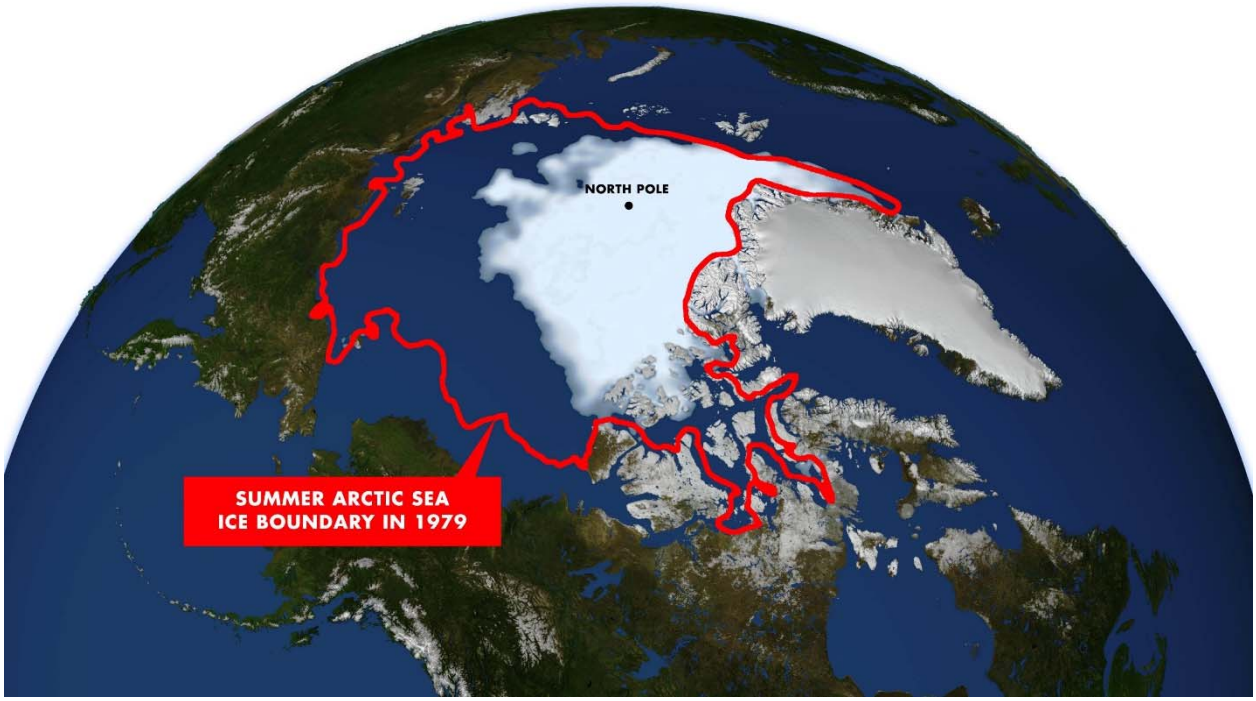

Arctic ice 2012
Source NASA

Author: Dr W R White

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1 Introduction

There is strong evidence that the Earth's climate has changed many times since the formation of Earth within the solar system some 4.6 billion years ago. Each change has had major implications on the ability of the Earth to support life of all kinds.

In historic times, say more than a million years ago, the evidence and the reasons for climate change are based upon assessments of a variety of complex phenomena. Whereas in very recent times, say within the last 200 years, advances in scientific instrumentation and knowledge have thrown more light on the subject. There is much more quantitative evidence available concerning such phenomena as atmospheric temperatures and composition, sea levels, ice quantities in the polar regions, etc., for this latter period.

The questions which attract the headlines and which could influence future life on the planet are:

- whether the observed current trends in climate change are man-made and cumulative and
- if so, whether the changes can be halted or at least slowed significantly.

This Review of Current Knowledge (ROCK) seeks to deal solely with the scientific evidence and is based heavily on the work of the Intergovernmental Panel on Climate Change (IPCC). As an intergovernmental body jointly established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), the Intergovernmental Panel on Climate Change has provided policymakers with the most authoritative and objective scientific and technical assessments. A series of IPCC Assessment Reports, Special Reports, Technical Papers, Methodology Reports and other products have been issued by the panel between 1990 and 2013.

The findings of the comprehensive IPCC 2013 report have been broadly accepted by the international community, culminating in the intergovernmental Paris Agreement of 2016. The central aim of the Paris Agreement is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century less than 2.0 deg C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 deg C. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. To reach these ambitious goals, appropriate financial flows, a new technology framework and an enhanced capacity building framework (social or personal development that focuses on understanding the obstacles that inhibit it) will be put

in place, thus supporting action by developing countries and the most vulnerable countries, in line with their own national objectives. The Agreement also provides for enhanced transparency of action and support through a more robust framework. The Agreement was signed by 117 Heads of Governments (or their representatives) on 22 April 2016 with an effective date of 4 November 2016.

The subjects of climate and climate change are enormous and embrace many scientific disciplines. There is a huge amount of literature on the subject from scientists around the globe. The IPCC 2013 Report alone runs to more than 1 500 pages. This ROCK sifts some of the more important fundamental issues and provides a bibliography for those wishing to take the subject further.

Chapter 2 gives information on the nature of climate, the factors which cause climate change and the way in which evidence is assembled for investigating historic climate change.

Chapter 3 describes some of the evidence for the historical climate changes which have occurred since the formation of the Earth some 4.6 billion years ago. The earliest climate change events were probably down to astronomical variations during the early development of the solar system.

Chapter 4 describes later times when anthropological and other effects came into play. These have been very noticeable since the start of the industrial revolution around 1800.

Chapter 5 looks more closely at the recent climate changes which are evident in the last 200 years or so.

Chapter 6 describes the potential effects of the current trends in climate change if they were to continue for the foreseeable future. Sophisticated climate models capable of evaluating numerous possible scenarios are used to make these predictions.

Chapter 7 explores how current trends can be reversed based on IPCC recommendations. It describes how the international community has agreed a way forward and how the UK is to participate in the process.

2 The nature of climate

One measure of climate change is a shift in the statistical distribution of weather patterns when that shift lasts for an extended period of time of perhaps decades to millions of years. A second measure may refer to a change in long term average weather conditions. A third measure may refer to more or fewer extreme events.

Factors that can affect climate are often referred to as “forcing mechanisms”. Examples of these mechanisms include:

- variations in solar radiation levels,
- variations in the Earth’s orbit,
- variations in reflected energy from land masses and the oceans,
- fluctuations in ocean currents,
- changes in the Earth’s atmosphere,
- continental drift,
- plate tectonics and mountain building,
- volcanic activity,
- biotic or anthropogenic changes.

These mechanisms can have a gradual or a rapid influence on climate. Changing temperatures in the oceans cause gradual change whereas certain types of volcanic eruption can cause more rapid change.

A climate record, extending deep into the Earth's past, has been assembled, and continues to be built up, based on geological evidence from:

- borehole temperature profiles,
- cores removed from deep accumulations of ice,
- floral and faunal records,
- glacial and periglacial processes,
- stable-isotope and other analyses of sediment layers,
- records of past sea levels.

More recent data covering the past 200 years are provided by routine measurements with scientific instruments of various kinds.

Scientists seek to understand climate by using observations and highly complex computer based models. These models, based on the physical sciences, are used to simulate past climate data, make future projections, and link the causes and the effects associated with climate change.

Review of Current Knowledge

Since the last ice age, which ended about 11 000 years ago, Earth's climate has been relatively stable with a mean atmospheric temperature of about 14 deg C. However, in the last 200 years, the average temperature has shown a systematic rise.

3 Historic changes in climate

Probably the most familiar periods when the Earth's climate was very unlike the climate we have today were during the ice ages. Evidence for the historical existence of major glaciation on the Earth's surface comes from three distinct sources. The interpretation of the evidence involves complex scientific reasoning which is beyond the scope of this text. In summary the evidence stems from:

- geological observations of glacial moraines, characteristic U-shaped valleys, deposition of till and glacial erratics,
- chemical analysis of fossils present in sediments and sedimentary rocks,
- changes in the geographical distribution of fossils caused by changes in temperatures in the higher latitudes.

The evidence from later ice ages tends to distort the evidence from earlier ones making interpretation quite difficult. Also some ice ages are more intense and widespread than others.

There have been at least five major ice ages in the Earth's past.

1. Huronian

This ice age formed around 2.1 to 1.4 billion years ago. Evidence of this ice age has been found as far afield as Canada, the USA and Western Australia.

2. Cryogenian

This ice age is well documented and occurred between 850 and 630 million years ago. It was probably the most severe ice age of the last billion years.

3. Andean-Saharan

This was a relatively short lived ice age which occurred between 460 and 420 million years ago.

4. Karoo

360 to 260 million years ago defines the period of the Karoo ice age. Extensive polar ice caps occurred and widespread evidence is to be found, for example, in Argentina, South Africa and the centre of the ancient supercontinent Gondwanaland.

5. Quaternary

This is regarded as the recent ice age which started around 2.6 million years ago. Since then the polar ice has advanced (glacial periods) and retreated (interglacial periods). The last glacial period ended around 10 000 years ago and all that remains of the continental ice sheets are to be found in Greenland and Antarctica.

The changes in the Earth's condition which precipitated these five ice ages is not known for certain. However the earliest, Huronian, ice age occurred only 2.2 to 2.4 billion years after the formation of the Earth. It was thus probably caused by some of the astronomical variations occurring during the formation of the solar system. The much later, Karoo, ice age is thought to have been initiated by the development of land plants on Earth. These plants, through photosynthesis, would have caused a long term increase in oxygen levels in the Earth's atmosphere and a reduction in carbon dioxide levels.

The linkage between the concentration of greenhouse gases in the atmosphere and average global temperature can be assessed for the last 800 000 years at least. The evidence comes from ice cores drilled in Antarctica and Greenland, see Plate 1. Snowfall has formed these ice sheets and on compaction and consolidation some of the air is trapped within the ice mass. Analysis of this trapped air yields information on the presence of greenhouse gases and their concentration. By analyzing the hydrogen and oxygen isotopes in the ice itself it is possible to estimate the air temperature when the water first froze.

Plate 1 The extraction of ice cores in Antarctica
Source: NASA Earth Observatory

Figure 1 shows the striking correlation between global mean surface temperatures and greenhouse gas concentrations for the last 800 000 years.

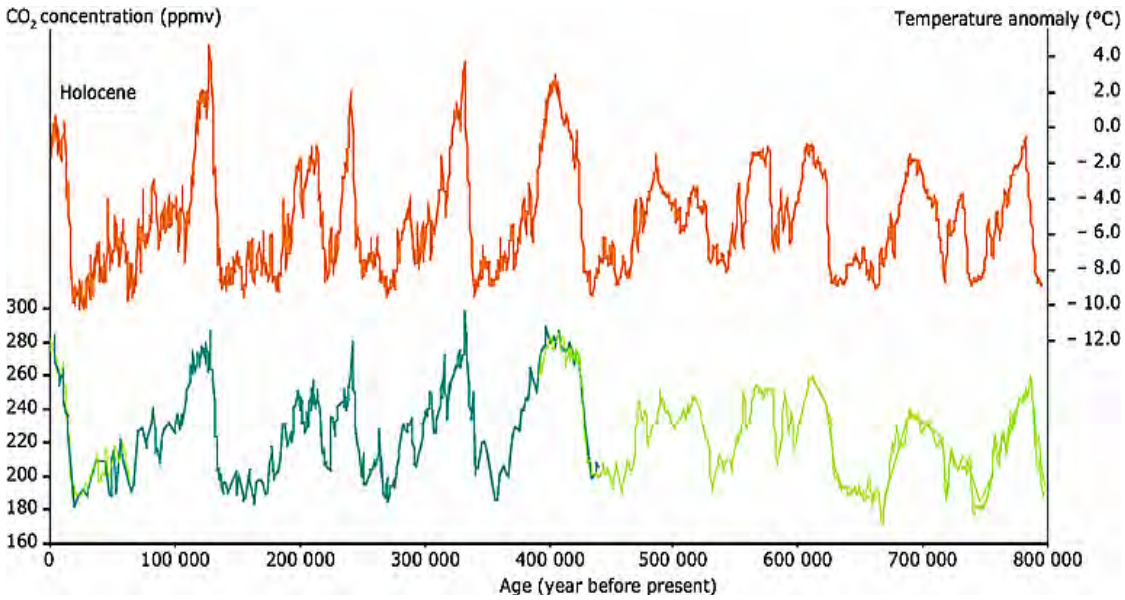

Figure 1 Historic global mean surface temperature versus the concentration of greenhouse gases
Source: www.eea.europa.eu

4 Recent changes in climate

A summary of the indicators of climate change can be found on the UK Met Office website (www.metoffice.gov.uk). This chapter is based on the Met Office commentary.

Climate change is a large-scale, long-term change in the planet's weather patterns or average temperatures. Earth has had tropical climates and ice ages many times in its 4.6 billion years.

Since the last ice age, which ended about 11 000 years ago, Earth's climate has been relatively stable with a mean surface air temperature of around 14 deg C. However, in the recent past, average atmospheric and surface temperatures have been increasing. Over the same period there has been a sharp increase in the concentration of greenhouse gases in the atmosphere.

Measurements of the atmospheric concentration of greenhouse gases have been made continuously from 1958 at the Mauna Loa Research Laboratory which is situated on the Pacific Ocean island of Hawaii. This site was chosen because it is remote and unaffected by local pollution. The results for the last 50 years are shown in Figure 2. Concentrations of carbon dioxide in the atmosphere have risen from 315 parts per million to 400 parts per million over that period.

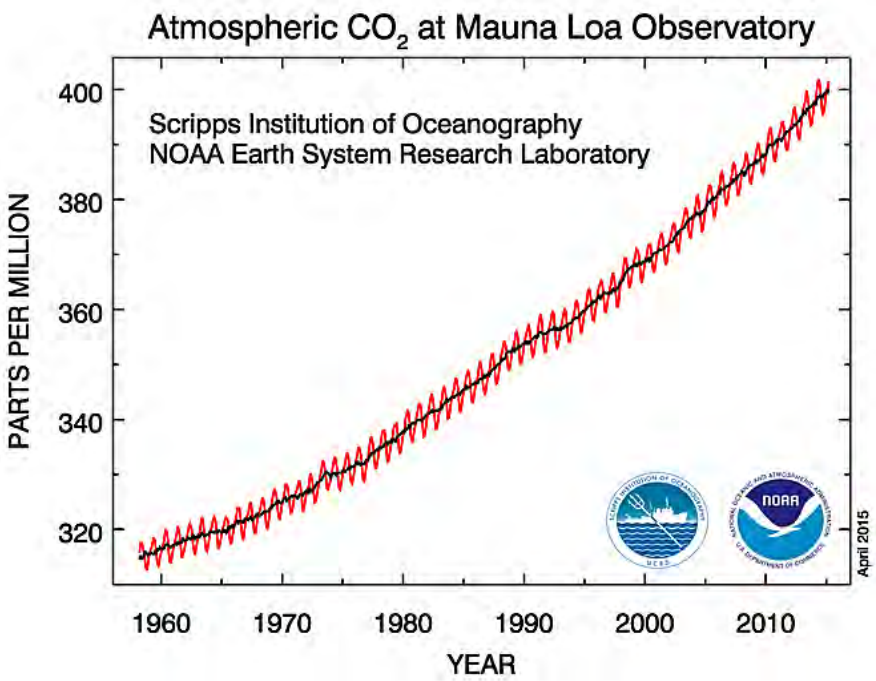

Figure 2 Greenhouse gas concentrations recorded at the Mauna Loa Observatory
Source: NOAA Earth System Research Laboratory

The information below details the seven main sources of evidence for climate change.

1. Temperatures

Scientific research shows that the global mean surface temperature has risen by 0.9 deg C from 1901 to 2012. Compared with climate change patterns throughout Earth's history, the rate of temperature rise since the start of the industrial revolution is extremely high, see Figure 3.

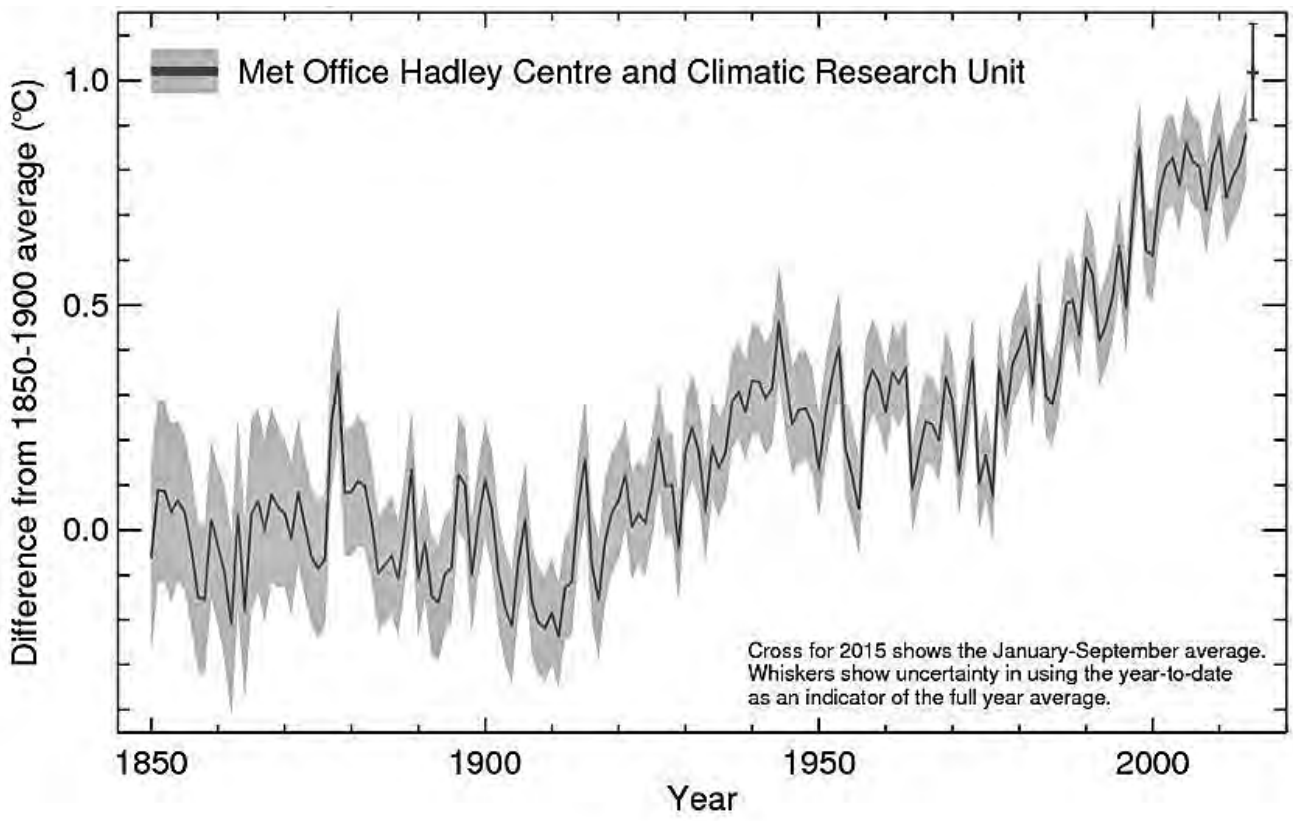

Figure 3 Global mean surface temperature 1880 to 2016
Source: www.metoffice.gov.uk

2. Precipitation

There have been observed changes in precipitation, but not all areas have data over long periods. Rainfall has increased in the mid-latitudes of the northern hemisphere since the beginning of the 20th century. There are also changes between seasons in different regions. For example, the UK's summer rainfall is decreasing on average, while winter rainfall is increasing. There is also evidence that heavy rainfall events have become more intensive, especially over North America.

Some more detailed historical data on rainfall over the UK is given by ***Osborne T and Maraun D, 2008*** (www.cru.uea.ac.uk)

3. Seasonal patterns

Changes in the seasons, such as the UK spring starting earlier and autumn starting later, are bringing changes in the behaviour of species, for example, butterflies appearing earlier in the year and birds shifting their migration patterns.

4. Mean sea level

Since 1900, mean sea levels have risen by about 10 cm around the UK and about 20 cm globally, on average. The rate of sea-level rise has increased in recent decades, see Figure 4.

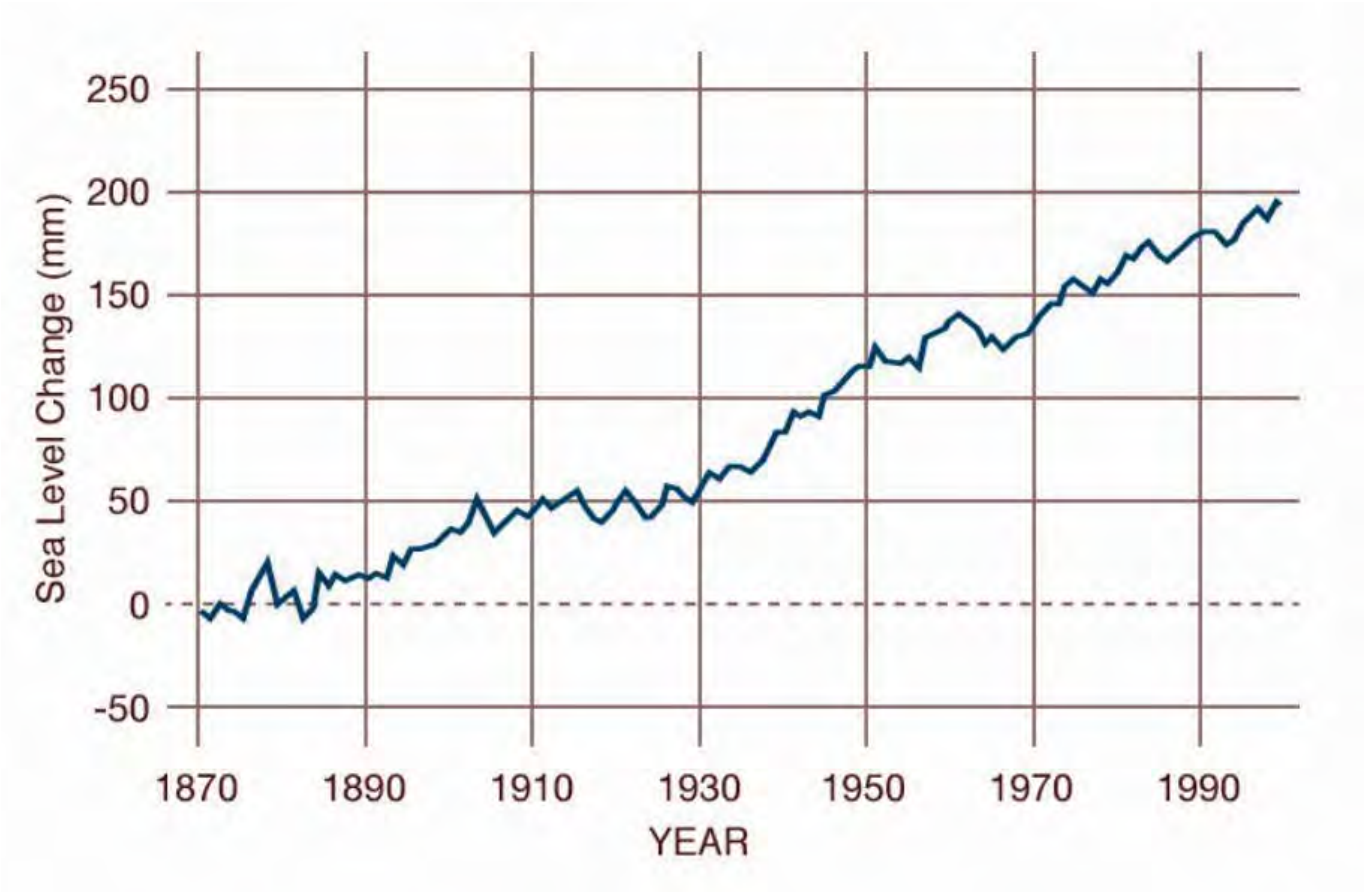

Figure 4 Global mean sea level changes 1870 to 2000
Source: http://climate.nasa.gov

5. Glaciers

Glaciers all over the world - in the Alps, Rockies, Andes, Himalayas, Africa and Alaska - are melting and the rate of shrinkage has increased in recent decades.

A well documented example of a retreating glacier is at the source of the Rhône in Switzerland, see Plate 2. Here the glacier has receded 1300m in the last 120 years.

Plate 2 Rhône glacier above Gletsch, Switzerland in 1900 (top) and 2008 (lower)
Source: www.swisseduc.ch

6. Sea ice

Sea ice floats on the surface of the oceans close to the North and South poles. The extent of the sea ice varies with season. Arctic sea-ice has been declining since the late 1970s, reducing by about 4 per cent, or 0.6 million square kilometres per decade, see Plate 3 for example. Over the same period Antarctic sea-ice has increased, but at a slower rate of about 1.5 per cent per decade.

Research is ongoing to establish the reasons for the differing behaviour of sea ice in the arctic and the antarctic regions. Studies are looking at the complex relationship between sea ice, which melts and reforms annually, and the adjacent areas of ocean.

Plate 3 Arctic sea ice in 1984 and 2012
Source: NASA Earth Observatory

7. Ice sheets

Ice sheets are large areas of ice which cover a land mass. The Greenland and Antarctic ice sheets, which between them store the majority of the world's fresh water, are both shrinking at an accelerating rate. This shrinking of the ice sheets is a significant factor in the rise of global sea levels. The Antarctic ice sheet is shown in Plate 4.

Plate 4 Antarctic ice sheet
Source: https://en.wikipedia.org

5 Causes of recent changes in climate

The IPCC 2013 Report indicates that it is extremely likely that there has been human influence in:

- warming of the atmosphere and the oceans,
- changes to the global water cycle,
- reductions in snow and ice,
- a rise in sea levels,
- changes in some climate extremes.

The functioning of global warming is illustrated in Plate 5.

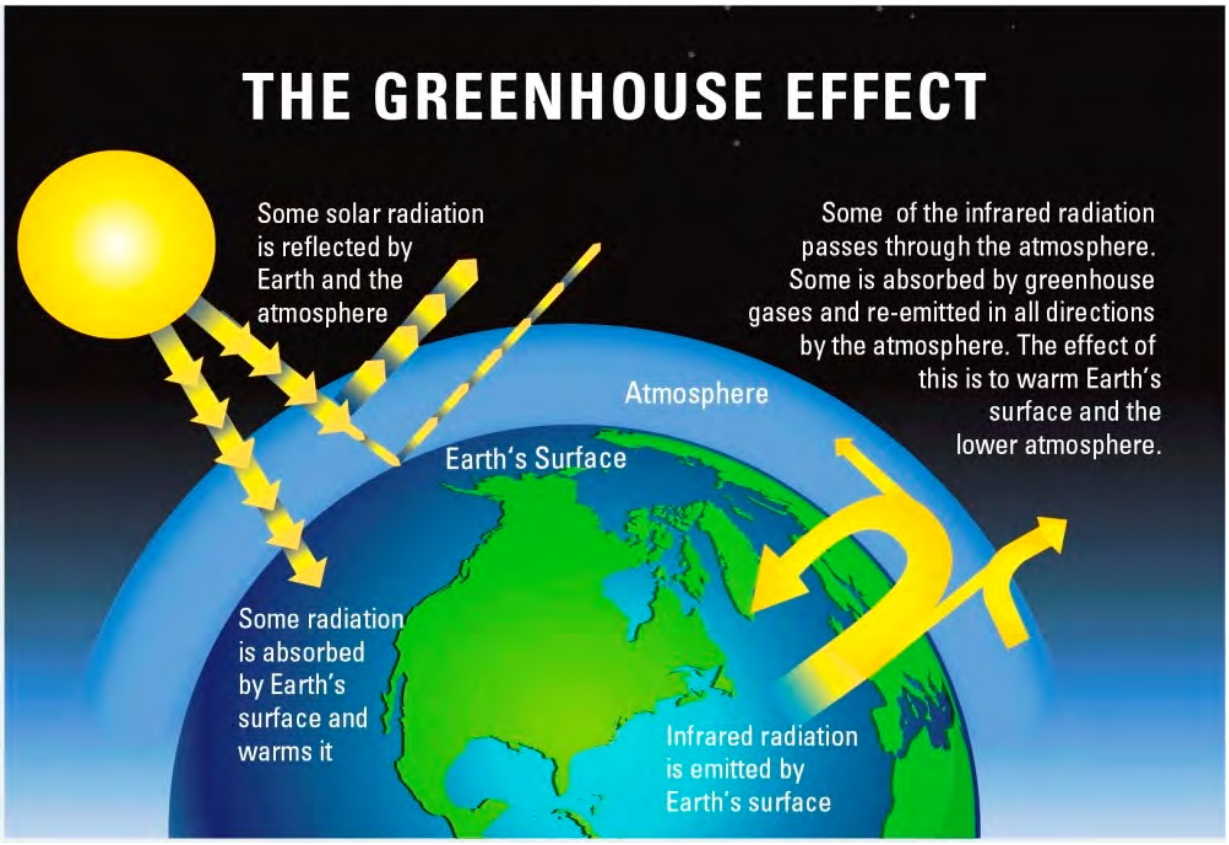

Plate 5 The greenhouse effect
Source: www.royalsociety.org

Greenhouse gas emissions into the atmosphere since 1800, the start of the industrial revolution, are shown in Figure 5. This data comes from the National Oceanic and Atmospheric Research Center, NOAA.

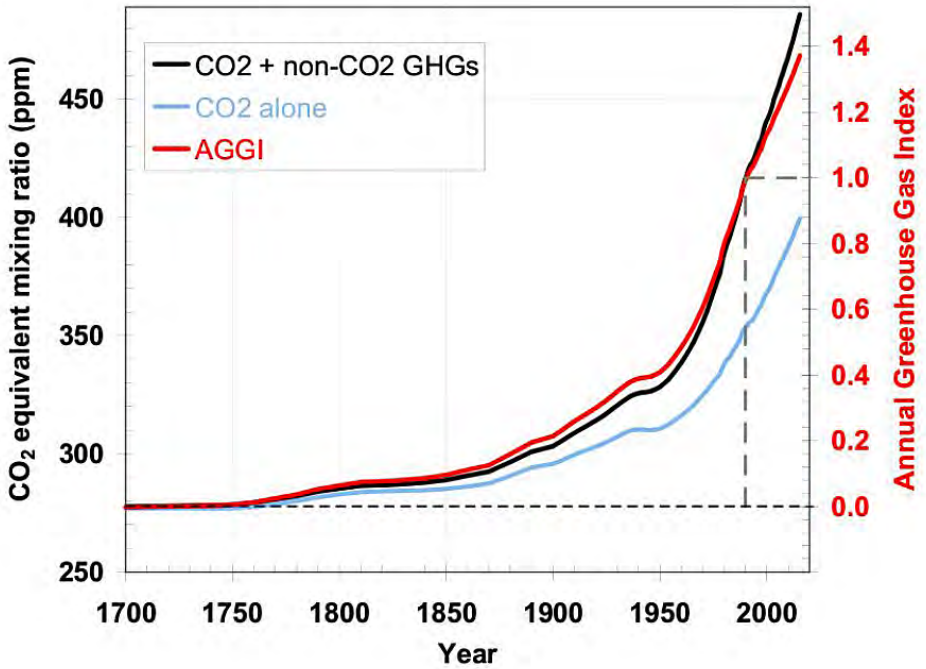

Figure 5 Greenhouse gas emissions to the atmosphere since 1800
Source: NOAA Earth System Research Laboratory

In 2015 the annual greenhouse gas emissions, by sector, are as shown in Plate 6. Power stations, industrial processes, agriculture and transportation dominate the picture.

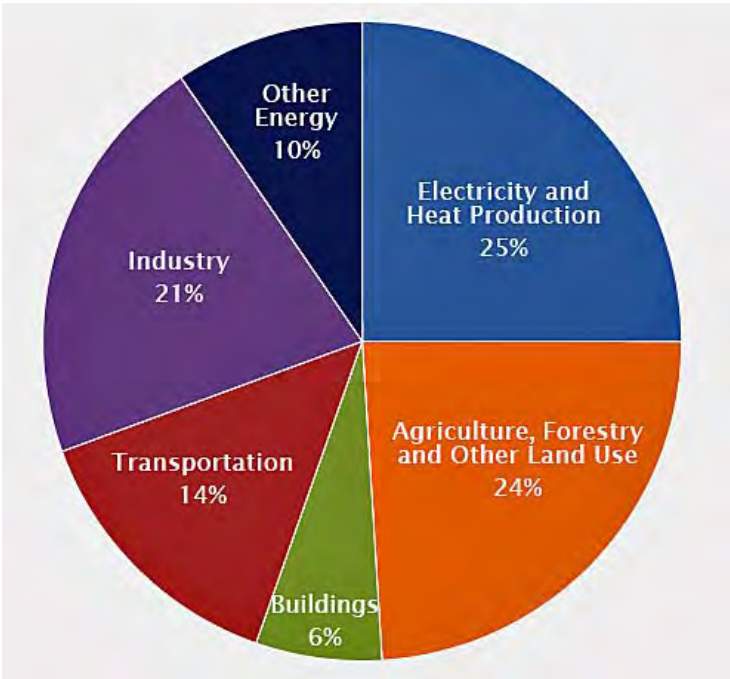

Plate 6 Current annual greenhouse gas emissions by sector
Source: US Environmental Protection Agency

The mix of greenhouse gas emissions, by gas, in 2015 is as shown in Plate 7.

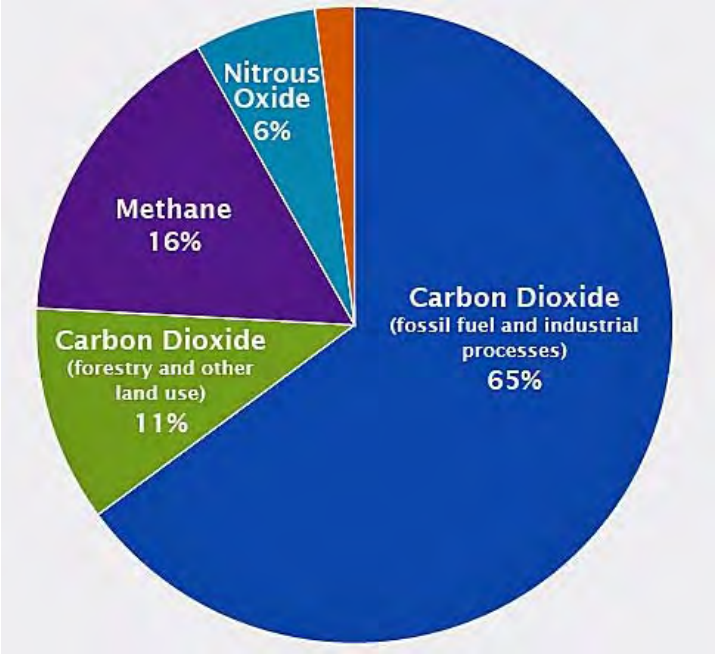

Plate 7 Current annual greenhouse gas emissions by gas
Source: US Environmental Protection Agency

The 2015 annual greenhouse gas emissions, by region, are as shown in Plate 8.

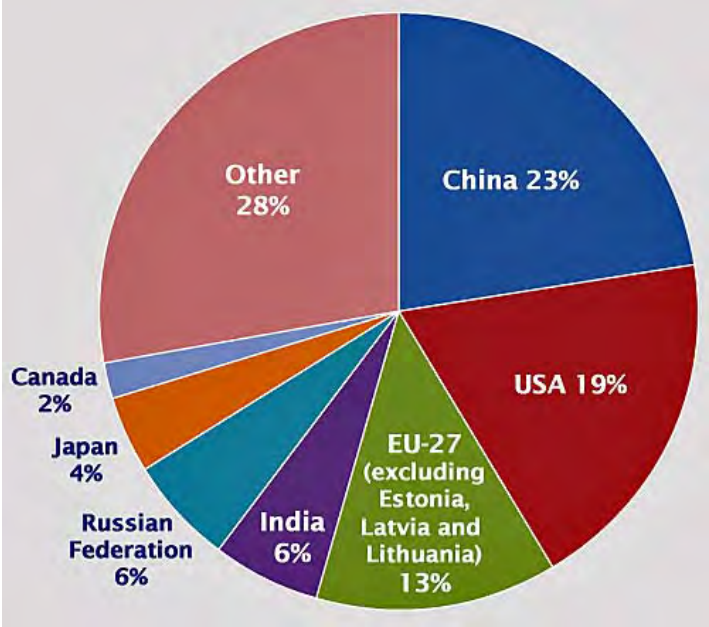

Plate 8 Current annual greenhouse gas emissions by region
Source: US Environmental Protection Agency

The distribution of greenhouse gas emissions from European countries between 1990 and 2014 is shown in Table 1. The figures in the table are given in million tonnes of carbon dioxide equivalent per annum.

Of the 28 countries listed, 24 have shown significant reductions in greenhouse gas emissions since 1990. Ireland, Spain, Cyprus and Malta have all shown increases.

In 2014 the five highest emissions came from Germany (21.9 per cent), the United Kingdom (12.6 per cent), France (10.8 per cent), Italy (9.7 per cent) and Poland (8.6 per cent). Taking into account the populations of these countries, emissions per head are Germany (12.0 tonnes), the United Kingdom (8.7 tonnes), France (7.2 tonnes), Italy (7.5 tonnes) and Poland (9.9 tonnes).

	1990	1995	2000	2005	2010	2014	Share in EU-28*
EU-28	**5 735.1**	**5 399.3**	**5 283.8**	**5 347.0**	**4 914.4**	**4 419.2**	**100.00%**
Belgium	149.2	156.9	153.9	148.4	137.5	117.9	2.67%
Bulgaria	104.8	74.4	58.5	63.2	60.3	55.4	1.25%
Czech Republic	199.8	158.7	151.5	149.7	141.1	126.8	2.87%
Denmark	72.4	80.4	73.4	69.3	66.0	53.9	1.22%
Germany	1 258.2	1 133.4	1 060.3	1 012.8	963.6	969.1	21.93%
Estonia	40.1	20.0	17.1	18.4	20.0	21.2	0.48%
Ireland	57.2	61.0	71.2	72.9	64.6	60.6	1.37%
Greece	107.3	113.4	130.2	138.4	120.8	104.3	2.36%
Spain	291.6	333.0	395.3	450.5	373.6	342.7	7.75%
France	556.8	557.7	568.8	570.6	530.7	475.4	10.76%
Croatia	35.2	24.6	27.1	31.3	29.2	24.8	0.56%
Italy	526.1	539.2	562.6	588.1	517.9	428.0	9.69%
Cyprus	6.4	7.9	9.2	10.2	10.4	9.2	0.21%
Latvia	26.4	12.9	10.5	11.6	12.6	11.6	0.26%
Lithuania	47.5	21.7	18.8	22.4	20.2	19.2	0.44%
Luxembourg	13.3	10.7	10.7	14.4	13.5	12.0	0.27%
Hungary	94.6	76.2	74.2	76.7	66.2	57.7	1.31%
Malta	2.2	2.8	3.0	3.2	3.4	3.3	0.08%
Netherlands	226.8	239.8	230.2	225.5	224.1	198.0	4.48%
Austria	79.7	81.2	82.1	94.8	87.0	78.3	1.77%
Poland	473.5	446.0	393.0	397.9	407.7	382.0	8.64%
Portugal	62.1	73.0	86.0	90.5	73.1	67.6	1.53%
Romania	252.7	183.4	140.9	147.0	117.5	110.4	2.50%
Slovenia	18.7	18.8	19.2	20.6	19.7	16.7	0.38%
Slovakia	74.8	54.8	50.0	51.6	46.7	40.8	0.92%
Finland	72.4	72.8	71.1	70.9	77.6	61.1	1.38%
Sweden	73.3	75.5	70.8	68.9	67.1	56.7	1.28%
United Kingdom	812.2	769.0	744.0	727.3	642.1	556.7	12.60%

*Share in EU-28 total in year 2014

Table 1 Greenhouse gas emissions from European countries
Source: http://ec.europa.eu/eurostat/

6 Potential effects of current trends in climate change

Projections of future changes in the climate system are made using computer models which vary in complexity. These models have been developed over many years and can simulate various scenarios of anthropogenic forcings. Details of current projections are given in the 2013 IPCC Report.

In general the models predict that continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial reductions in greenhouse gas emissions.

The 2013 IPCC Report details results for a multitude of assumed anthropogenic scenarios, the details of which are beyond the scope of this ROCK. The probability of the changes predicted by the models actually occurring is qualitatively defined by such terms as *very high confidence*, *high confidence*, *likely* and *more likely than not*. A somewhat simplified summary of those scenarios quoted in this ROCK is given below.

In broad terms, these four *representative concentration pathways* (RCPs) can be regarded as:

RCP2.6 – a set of measures which would mitigate climate change,
RCP4.5 and RCP6.0 – sets of measures which would stabilize climate change,
RCP8.5 – a scenario with continued high greenhouse gas emissions.

1. Atmospheric temperature

Global mean surface temperature to the end of the 21st century is *likely* to exceed 1.5 deg C relative to 1800 - 1850 levels for all the anthropogenic scenarios tested. Some scenarios gave greater increases in temperature. The results are shown in Figure 6.

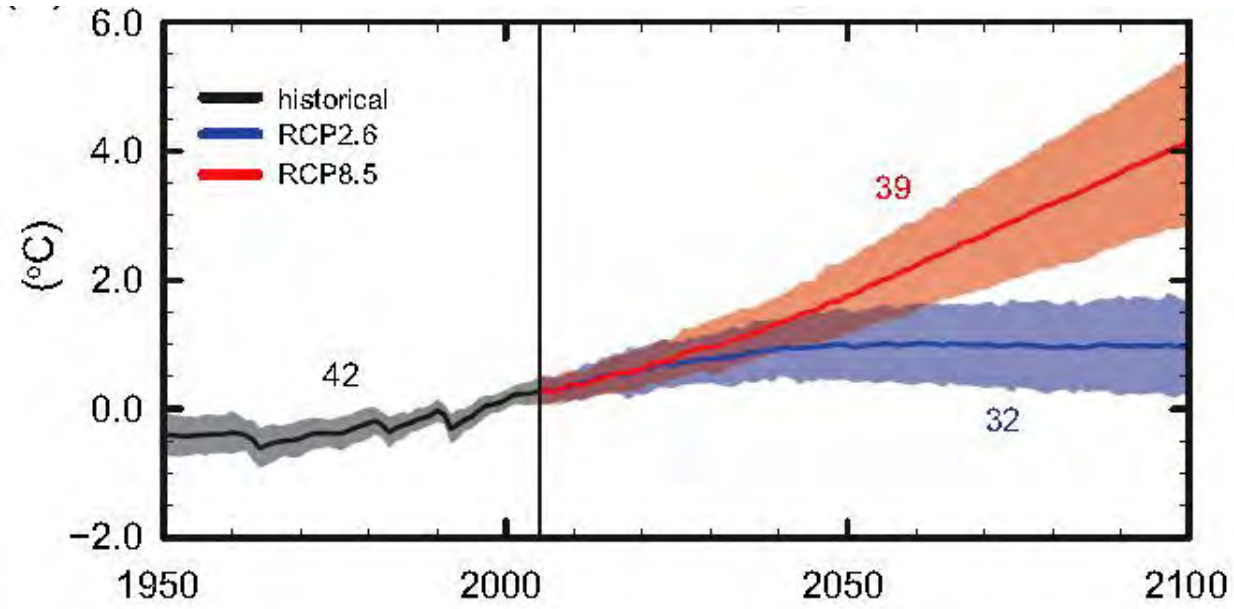

Figure 6 Predictions for global mean surface temperature rises to 2100
Source: IPCC 2013 Report

2. ***Water cycle***

Changes in the global water cycle in response to the warming over the 21st century is *likely* and will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions.

Plate 9 shows predictions for changes to the worldwide average precipitation.

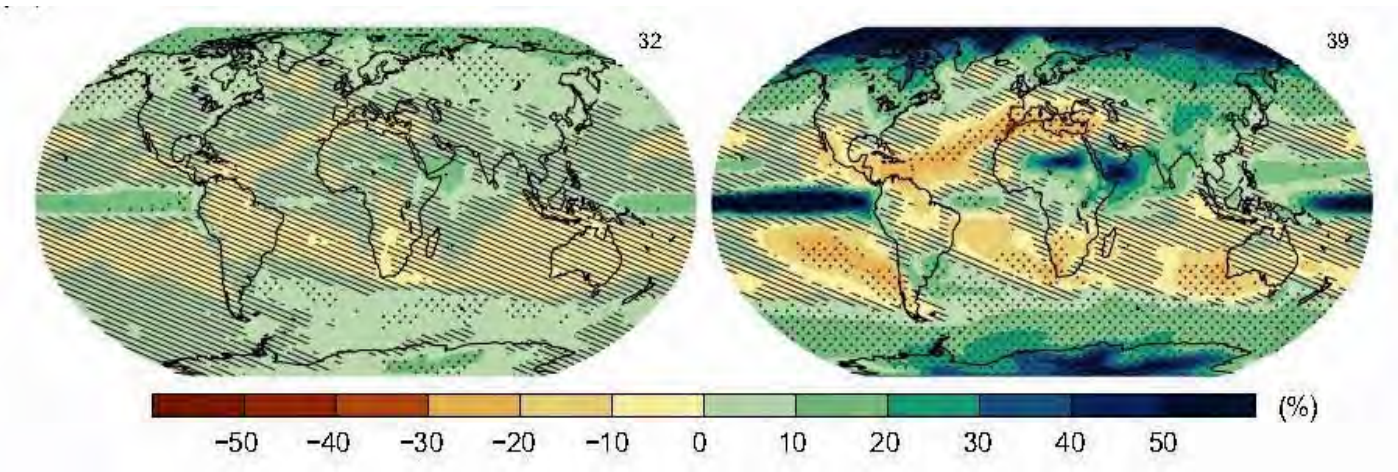

Plate 9 Predictions for changes in average precipitation from 2013 to 2100
Source: IPCC 2013 Report

3. ***Air quality***

Air quality is driven primarily by emissions rather than by physical climate change. No firm findings are given in current IPCC documentation.

4. ***Ocean temperature***

It is *very likely* that the global oceans will continue to warm during the 21st century. Heat will penetrate from the surface to the deep ocean and affect ocean circulation.

5. ***Cryosphere***

It is *very likely* that the Artic sea ice cover will continue to shrink and thin and that the Northern Hemisphere spring snow cover will decrease during the 21st century as global mean surface temperatures rise. Global glacier volume will further decrease.

6. ***Mean sea level***

Global mean sea level will continue to rise during the 21st century. Under all anthropological scenarios the rate of sea level rise will *very likely* exceed that observed during the last 50 years. This is mainly due to increased sea temperatures and continued loss of mass from glaciers and ice sheets.

The projected rise in sea level is shown in Figure 7.

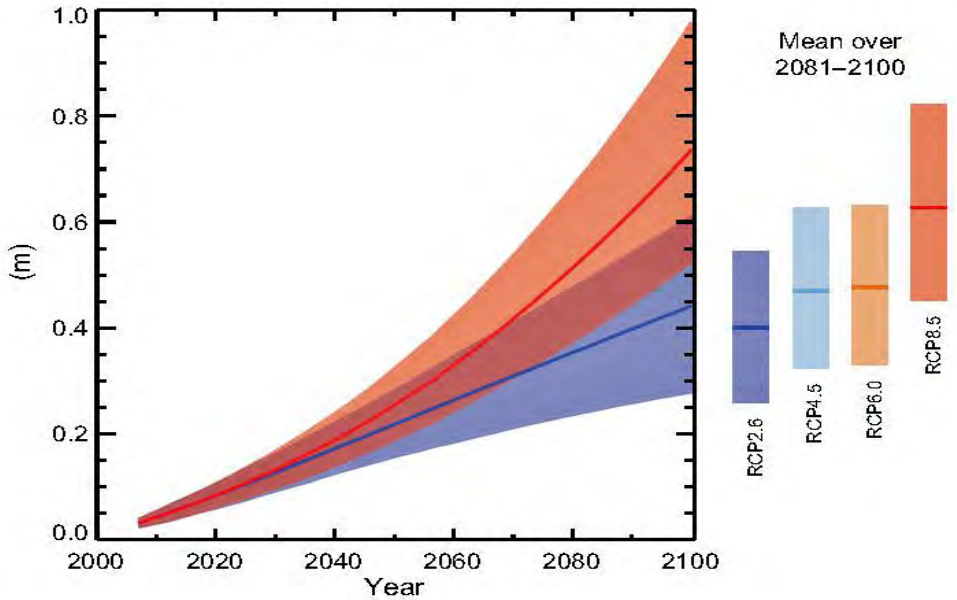

Figure 7 Predictions for rise in global mean sea level to 2100
Source: IPCC 2013 Report

7. Carbon and other biogeochemical cycles

Climate change is predicted with *high confidence* to affect carbon cycle processes in a way that will exacerbate the increase in carbon dioxide in the atmosphere. Further uptake of carbon by the ocean is predicted to increase ocean acidification.

7 Climate stabilization

7.1 IPCC Recommendations

Cumulative emissions of carbon dioxide largely determine global mean surface warming by the late 21st century and beyond. Most aspects of climate change will persist for many centuries even if carbon dioxide emissions were to cease altogether. This represents a substantial multi-century climate change commitment created by past, present and future carbon dioxide emissions.

The IPCC 2013 Report indicates scenarios for the mitigation or at least the stabilization of change as previously indicated in the *representative concentration pathways* RCP2.6, RCP4.5, RCP6.0 and RCP8.5.

The requirements for baseline and mitigation scenarios are illustrated in Figure 8.

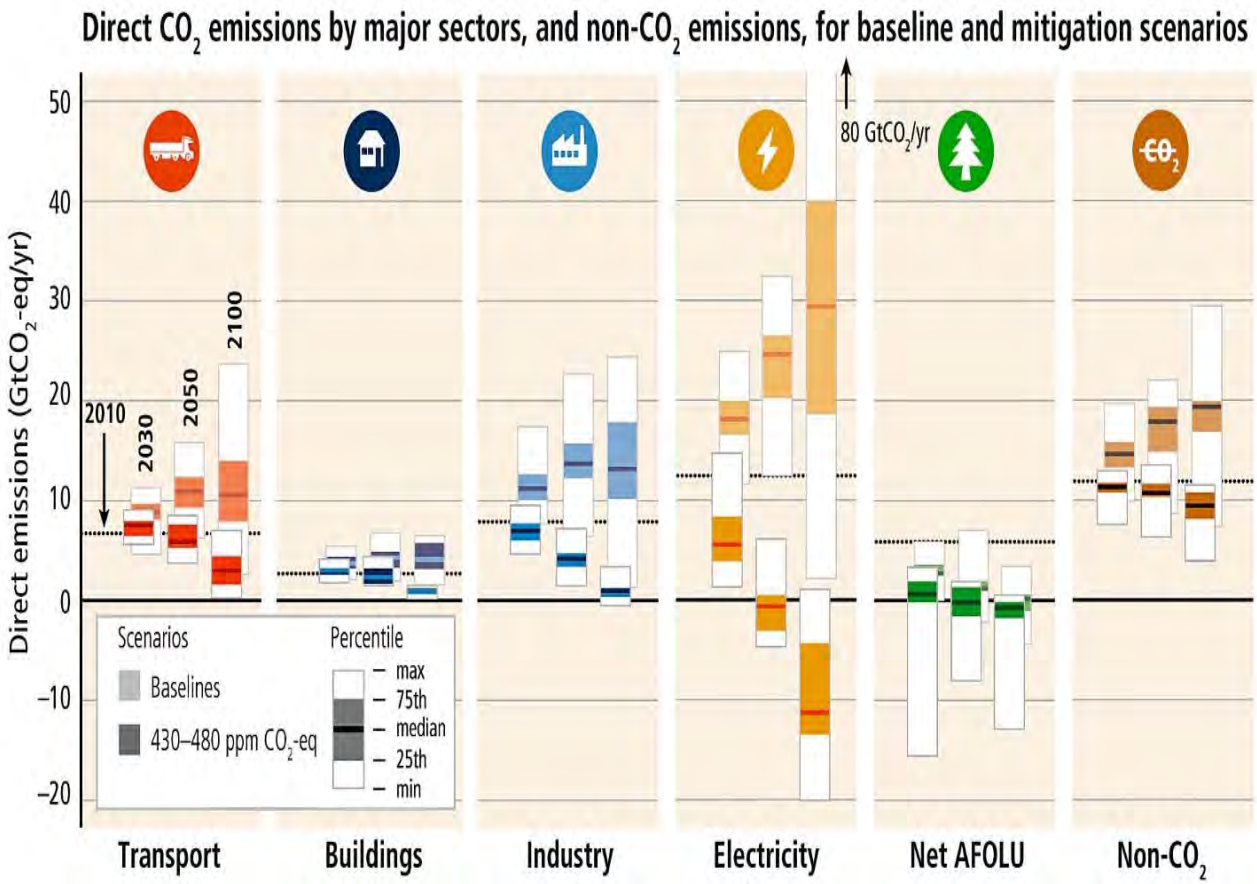

Figure 8 Requirements for the mitigation of climate change
Source: IPCC 2013 Report

1. Temperature rise

The IPCC 2013 Report suggests, with various degrees of probability, that drastic reductions in carbon dioxide emissions are necessary if global temperature rise from 1880 figures is to be kept to between 1.5 deg C and 2.0 deg C. This drastic reduction is partially explained by the fact that many of the effects of carbon dioxide emissions during the last 200 years are irreversible. Again, details are to be found in IPCC reports.

Data exists for global increases in temperature from around 1870. Increases are directly related to the cumulative total of anthropogenic carbon dioxide emissions. Historic data and models using most anthropogenic assumptions yield this conclusion. The data is shown in Figure 9.

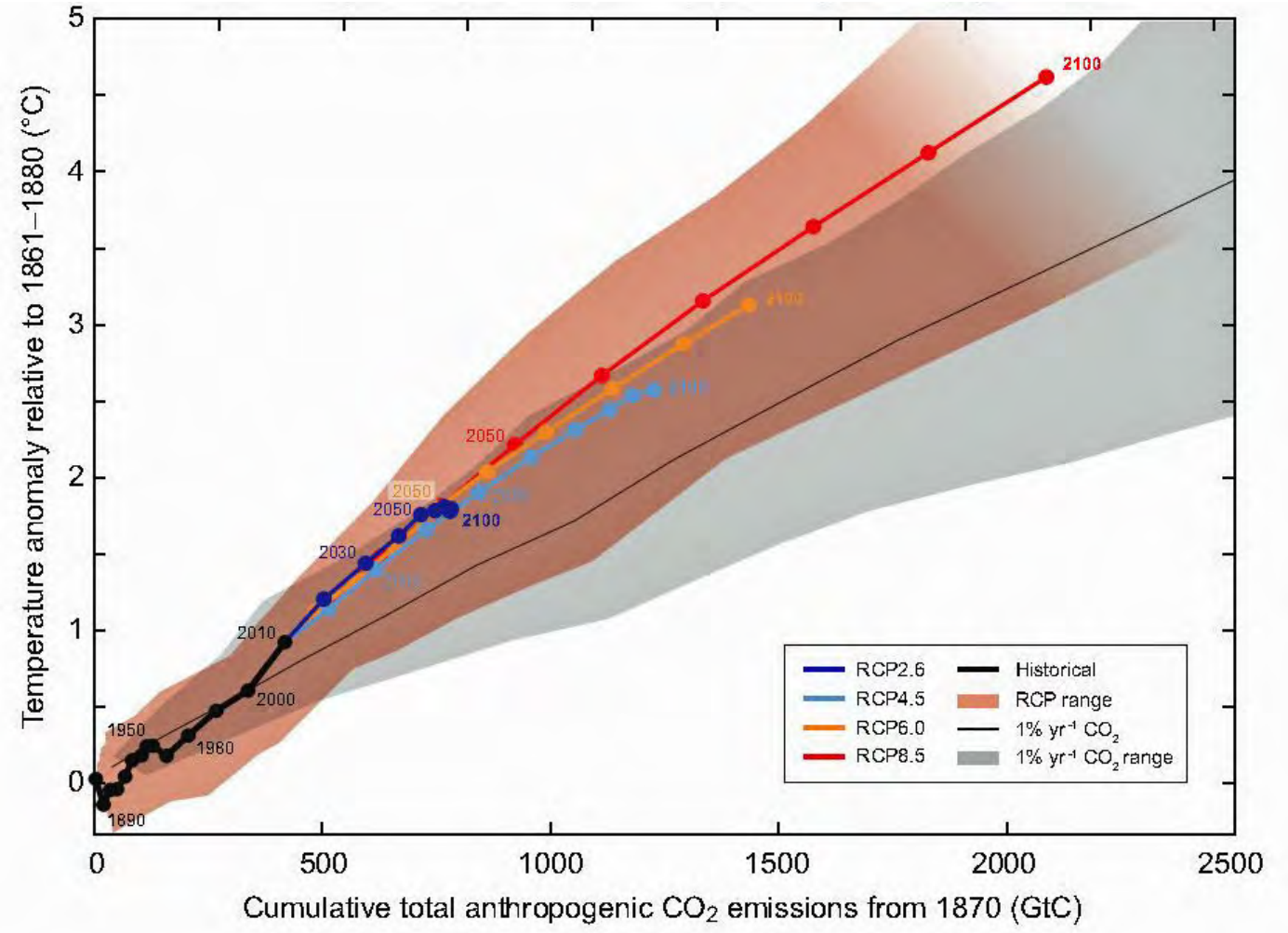

Figure 9 Temperature rise versus cumulative carbon dioxide emissions from 1870
Source: IPCC 2013 Report

2. Mean sea level rise

The IPCC 2013 Report looks at various scenarios which might affect sea level rise. It suggests that sea levels will continue to rise well beyond 2100 and that the magnitude of this rise could be between 1 metre and 4 metres above 1880 levels.

7.2 The Paris Agreement of 2016

The Paris Agreement was drafted in late 2015, signed in April 2016 to take effect from November 2016. It was ratified by 55 members of the United Nations Framework Convention on Climate Change (UNFCCC) accounting for 55 per cent of global greenhouse emissions. Ratification is open until 21 April 2017 and currently stands at 132 members.

1. Aims

The aim of the Agreement is to enhance the implementation of the United Nations Framework Convention on Climate Change through:

- Holding the increase in the global average temperature to well below 2.0 deg C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 deg C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change,
- Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production,
- Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

Participating countries, furthermore, aim to reach global peaking of greenhouse gas emissions as soon as possible. The Agreement has been described as an incentive for, and driver of, reducing the use of fossil fuels.

The Paris Agreement is the world's first comprehensive climate agreement.

2. Nationally determined contributions and their limits

The contribution that each individual country should make in order to achieve the worldwide goal is determined by all countries individually and called *nationally determined contributions*. These contributions are to be ambitious, to represent a progression over time, and to be set with a view to achieving the purpose of the Agreement. The contributions should be reported every five years and are to be

registered by the UNFCCC Secretariat. Each further ambition should be more ambitious than the previous one, known as the principle of 'progression'. Countries can cooperate and pool their nationally determined contributions.

The *nationally determined contributions* themselves are not binding as a matter of international law, as they lack the specificity, normative character, or obligatory language necessary to create binding norms. Furthermore, there will be no mechanism to force a country to set a target in their *nationally determined contribution* by a specific date and no enforcement if a set target is not met. There will be only a "name and shame" system.

The negotiators of the Agreement however stated that the 2.0 deg C reduction target was insufficient. Instead, a 1.5 deg C target is required. The negotiators noted with concern that the estimated aggregate greenhouse gas emission levels in 2025 and 2030 resulting from the intended *nationally determined contributions* are unlikely to restrict temperature rises to 2.0 deg C by 2100. Much more ambitions targets are required, certainly if the 1.5 deg C goal is to be achieved.

When the Agreement achieved enough signatures to cross the threshold of acceptance in October 2016, the US President stated that "Even if we meet every target, we will only get to part of where we need to go." and that "This Agreement will help delay or avoid some of the worse consequences of climate change and will help other nations ratchet down their emissions over time."

7.3 UK climate action following the Paris Agreement

The United Kingdom set up an independent, statutory committee under the Climate Change Act of 2008 with the title of Committee on Climate Change (CCC). The purpose of this committee is to advise the UK Government and Devolved Administrations on emissions targets and report to Parliament on progress made in reducing greenhouse gas emissions and preparing for climate change.

In fulfilling this role the focus is to:

- Provide independent advice to Government on setting and meeting carbon budgets and preparing for climate change,
- Monitor progress in reducing emissions and achieving carbon budgets,
- Conduct independent analyses into climate change science, economics and policy,
- Engage with a wide range of organisations and individuals to share evidence and analysis.

Review of Current Knowledge

In October 2016, immediately following the Paris Agreement, the Committee on Climate Change issued a report describing the current UK plans for reducing carbon emissions.

There follows a very brief summary of the findings of this report. Readers are referred to the report itself for details.

1. Summary

The Committee on Climate Change (CCC) summarized the UK position as follows:

- The UK already has stretching targets to reduce greenhouse gas emissions. Achieving them will provide a positive contribution to global climate action. In line with the Paris Agreement the UK Government is committed, at some point, to reduce domestic emissions to net zero. An increased contribution from the UK will be considered at the five yearly global pledges and reviews.
- The UK will vigorously pursue the measures required to deliver on existing UK commitments and maintain the flexibility to go further. This will require the construction, publication, and execution of a robust plan to meet the emissions targets.
- The UK requires a strategy for developing options to remove greenhouse gases from the air. These are associated with aviation, agriculture and parts of industry. Greenhouse gas removal options including afforestation, carbon storing materials, bioenergy with carbon capture and storage will need to be developed if the UK is to meet net zero emissions by 2050.

2. Details

The Executive Summary of the report of the Committee on Climate Change gives many detailed facts and recommendations under four headings:

- UK and international ambition,
- Net zero emissions,
- Strategies for hard-to-treat sectors and greenhouse gas removals,
- Implications for UK policy priorities in the nearer-term.

3. Supporting analysis

The analyses underpinning the recommendations of the report are given in the final four chapters entitled:

- Current UK ambition and the Paris Agreement,
- Implications of Paris ambition for emissions in 2050 and beyond,
- Feasibility of the UK taking more ambitious domestic action,
- Considerations in setting UK policy to reflect Paris ambition.

Readers are referred to the full report for details, see https://www.theccc.org.uk/
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